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(54) Increased production of thermus aquaticus DNA polymerase in *E. coli*.

(57) The *Thermus aquaticus* gene encoding a thermostable DNA polymerase (Taq Pol) is altered in the N-terminus-encoding region to provide mutant genes with improved expression in *E. coli*.

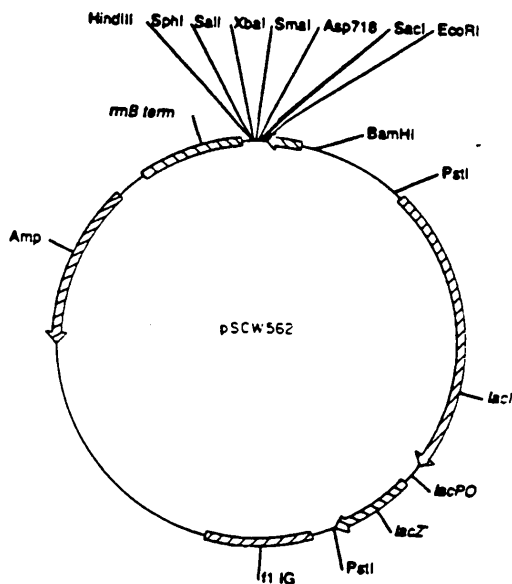


FIG. 1

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This invention relates to the field of genetic engineering. More particularly, this invention relates to the alteration of a native gene to provide a mutant form having improved expression in *E. coli*.

One of the major achievements in recombinant technology is the high-level expression (overproduction) of foreign proteins in procaryotic cells such as *Escherichia coli* (*E. coli*). In recent years, this technology has improved the availability of medically and scientifically important proteins, several of which are already available for clinical therapy and scientific research. Overproduction of protein in procaryotic cells is demonstrated by directly measuring the activity of the enzyme with a suitable substrate or by measuring the physical amount of specific protein produced. High levels of protein production can be achieved by improving expression of the gene encoding the protein. An important aspect of gene expression is efficiency in translating the nucleotide sequence encoding the protein. There is much interest in improving the production of bacterial enzymes that are useful reagents in nucleic acid biochemistry itself, for example, DNA ligase, DNA polymerase, and so forth.

Unfortunately, this technology does not always provide high protein yields. One cause of low protein yield, is inefficient translation of the nucleotide sequences encoding the foreign protein. Amplification of protein yields depends, inter alia, upon ensuring efficient translation.

Through extensive studies in several laboratories, it is now recognized that the nucleotide sequence at the N-terminus-encoding region of a gene is one of the factors strongly influencing translation efficiency. It is also recognized that alteration of the codons at the beginning of the gene can overcome poor translation. One strategy is to redesign the first portion of the coding sequence without altering the amino acid sequence of the encoded protein, by using the known degeneracy of the genetic code to alter codon selection.

However, the studies do not predict, teach, or give guidance as to which bases are important or which sequences should be altered for a particular protein. Hence, the researcher must adopt an essentially empirical approach when he attempts to optimize protein production by employing these recombinant techniques.

An empirical approach is laborious. Generally, a variety of synthetic oligonucleotides including all the potential codons for the correct amino acid sequence is substituted at the N-terminus encoding region. A variety of methods can then be employed to select or screen for one oligonucleotide which gives high expression levels. Another approach is to obtain a series of derivatives by random mutagenesis of the original sequence. Extensive screening methods will hopefully yield a clone with high expression levels. This candidate is then analyzed to determine the "optimal" sequence and that sequence is used to replace the corresponding fragments in the original gene. This shot-gun approach is laborious.

These tedious strategies are employed to amplify the synthesis of a desired protein which is produced by the unaltered (native) gene only in small quantities. The thermostable DNA polymerase from *Thermus aquaticus* (Taq Pol) is such a product.

Taq Pol catalyzes the combination of nucleotide triphosphates to form a nucleic acid strand complementary to a nucleic acid template strand. The application of thermostable Taq Pol to the amplification of nucleic acid by polymerase chain reaction (PCR) was the key step in the development of PCR to its now dominant position in molecular biology. The gene encoding Taq Pol has been cloned, sequenced, and expressed in *E. coli*, yielding only modest amounts of Taq Pol.

The problem is that although Taq Pol is commercially available from several sources, it is expensive, partly because of the modest amounts recovered by using the methods currently available. Increased production of Taq Pol is clearly desirable to meet increasing demand and to make production more economical.

FIG.1, the sole illustration, shows the relevant genetic components of a vector, pSCW562, used to transform an *E. coli* host.

The present invention provides a gene for Taq polymerase wherein the sequence of the first thirty nucleotide bases in the native gene which code for the first ten amino acids in the mature native protein, has been changed

A) by substituting therefor a modified nucleotide sequence selected from the group consisting of:

SEQ ID NO: 2:

ATG CGT GGT ATG CTG CCT CTG TTT GAG CCG AAG , 33

5

SEQ ID NO: 3:

ATG CGT GGG ATG CTG CCC CTC TTT GAG CCC AAG , and 33

10

SEQ ID NO: 4:

ATG GAC TAC AAG GAC GAC GAT GAC AAG CGT GGT ATG 36
CTG CCC CTC TTT GAG CCC AAG , 57

15

or

B) by inserting between the codon (ATG) for the first amino acid of the mature native protein and the codon, (AGG) for the second amino acid of the mature native protein, the sequence:

20

SEQ ID NO: 5:

GAC TAC AAG GAC GAC GAT GAC AAG . 24

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The invention also provides a method of increasing the production of Taq Pol by using the above altered genes.

The invention provides enhanced polymerase activity levels as high as 200-fold. The recombinant polymerase of this invention is functionally indistinguishable from native Taq Pol.

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1. Introduction

The object of the present invention is to increase the production of Taq polymerase in *E. coli* by changing selected nucleotide sequences in the 5' region of the gene which encode the N-terminus of the polymerase.

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The invention provides four nucleotide sequences which differ from the native *Thermus aquaticus* polymerase (Taq Pol) gene in one to several nucleotides. When introduced into the native gene and transfected into *E. coli*, these DNA sequences provide improved expression of the gene, evidenced by increased activity of the enzyme. The amount of increase varies widely depending on the nucleotide changes made and also on other factors such as induction with IPTG, incubation period of *E. coli*, and so forth.

40

The genes provided by the present invention are the same as the native Taq Pol gene except for changes in the native sequence made in accordance with the present invention. Where these changes are made, they are specifically described and shown in the examples and in the Sequence Listing. Changes are only in the region encoding the N-terminus of the protein. More specifically, changes are made only in the region upstream of the eleventh codon (AAG) coding for the eleventh amino acid (lysine) in the mature native protein. The eleventh codon is not changed, but it is shown in the sequence listing as the bracket or the point above which changes are made in the practise of the invention. Except for these identified changes, the remaining sequence of the Taq Pol gene remains unchanged.

45

50

The term "Taq Pol gene" as used herein refers to the nucleotide sequence coding for the thermostable DNA polymerase of *Thermus aquaticus* and includes mutant forms, spontaneous or induced, of the native gene as long as the mutations do not confer substantial changes in the essential activity of the native polymerase

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The term "Taq Pol" as used herein refers to the polymerase encoded by the Taq Pol gene.

The term "native" as used herein refers to the unaltered nucleotide sequence of the Taq Pol gene or the unaltered amino acid sequence of the Taq polymerase as that gene or enzyme occurs naturally in *T. aquaticus*. See SEQ ID NO:1.

In general terms, the invention comprises the following steps:

A) providing a vector with a Taq Pol gene of the invention,

B) transfecting compatible E. coli host cells with the vector of A) thereby obtaining transformed E. coli host cells; and

C) culturing the transformed cells of B) under conditions for growth thereby producing Taq polymerase synthesized by the transformed host cells.

The following bacterial strains, plasmids, phage and reagents were used in the invention.

2. Bacterial Strains

Thermus aquaticus YT-1, ATCC No. 25104, was used for native DNA isolation. The host E. coli strain for all cloning and plasmid manipulation, DH5 α [F⁻ θ 80dlacZ Δ M15 Δ (lacZYA-argF)U169 recA1 endA1 hsdR17-(r κ ⁻, m κ ⁻) supE44 thi1 gyrA relA1] was obtained from BRL.

Strain JM103 [thi⁻, strA, supE, endA, sbcB, hsdR⁻, D(lac-pro), F' traD36, proAB, lacI^q, lacZDM15) (Yanisch-Perron and others, Improved M13 Phage Cloning Vectors and Host Strains: Nucleotide Sequences of M13mp18 and pUC19 Vectors, Gene 33:103-119 (1985)) was also utilized for protein expression experiments.

The host strain for preparation of single-stranded DNA for use in mutagenesis was CJ236 (pCJ105, dut ung thi relA) (Kunkel and others, Rapid and Efficient Site-specific Mutagenesis without Phenotypic Selection, Methods Enzymol 154:367-382, (1987)).

The f1 phage R408 (Russel and others, An Improved Filamentous Helper Phage for Generating Single-stranded DNA, Gene 45:333-338 (1986)) was used as the helper to generate single-stranded plasmid DNA for mutagenesis. The plasmid used for all cloning and expression work was pSCW562 or its derivative pTaq1. A diagram of pSCW562 is shown in Figure 1. When the native Taq Pol gene is inserted into pSCW562, the resulting plasmid is designated pTaq1. When the native Taq Pol gene is altered by mutagenesis, the mutant plasmid is designated pTaq3, pTaq4, pTaq5, or pTaq6 depending on the nucleotide sequence with which it is mutagenized.

3. Reagents

Chemicals were purchased from Sigma, International Biotechnologies, Inc. or Eastman Kodak. LB medium was obtained from Gibco. Enzymes were purchased from New England Biolabs, IBI, BRL, Boehringer-Mannheim, or U.S. Biochemicals and were used as recommended by the supplier. SequenaseTM kits for DNA sequencing were obtained from U.S. Biochemicals. Radioisotopes were purchased from Amersham. Taq polymerase was purchased from Cetus.

4. Method of Increasing the Production of Taq Pol

Step A - Providing a Vector with the Taq Pol Gene of the Invention

One method of providing a vector with the Taq Pol gene of the invention is to:

- provide the native DNA from Thermus aquaticus;
- amplify the native Taq Pol DNA and incorporate restriction sites at both ends of the DNA fragments,
- ligate the DNA fragments of ii) into a suitable vector,
- use site-directed mutagenesis to change the nucleotide sequence of the native DNA, and
- screen for vectors carrying the changed nucleotide sequence of the invention.

i. Providing the Native Gene from T. aquaticus

All DNA manipulations were done using standard protocols (Maniatis and others, Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York, 1982 and Ausubel and others, Current Protocols in Molecular Biology, John Wiley and Sons, New York, New York, 1987). Total DNA from T. aquaticus (strain YT-1, [ATCC No. 25104]) was isolated from a 40 mL culture of the organism grown overnight at 70°C in ATCC medium #461. The cells were pelleted by centrifugation, washed once with 10 mM Tris HCl, pH 8.0, 1 mM ethylenediaminetetraacetic acid (EDTA), 10 mM Tris HCl (pH 8.0) (TE), and resuspended in 5 mL of TE. Lysozyme was added to a concentration of 1 mg/mL and the solution was incubated at 37°C for 30 minutes. EDTA, sodium dodecyl sulfate (SDS) and proteinase K were added to concentrations of 50 mM, 0.5% and 100 μ g/mL, respectively, and the solution was incubated for 4 hours at

50 °C. The sample was extracted three times with phenol-chloroform and once with chloroform and the DNA was precipitated by addition of sodium acetate to 0.3 M and two volumes of ethanol. The DNA was collected by spooling on a glass rod, washed in 70% ethanol, and dissolved in (TE).

5 ii. Amplifying the Native Taq Pol Gene and Incorporating Restriction Sites

The fastest approach to producing large amounts of Taq Pol gene is to utilize the published nucleic acid sequence of the gene (Lawyer and others, Isolation, Characterization and Expression in *Escherichia coli* of the DNA Polymerase from *Thermus aquaticus*, Journal of Biological Chemistry, 264:6427-6437, 1989) to
10 design oligonucleotide primers that can be used in PCR to amplify genomic DNA. See SEQ ID NO: 1: for entire gene sequence.

PCR is an amplification technique well known in the art (Saiki and others, Primer-directed Enzymatic Amplification of DNA with a Thermostable DNA Polymerase, Science 239:487-491 (1988)), which involves a chain reaction producing large amounts of a specific known nucleic acid sequence. PCR requires that the
15 nucleic acid sequence to be amplified must be known in sufficient detail so that oligonucleotide primers can be prepared which are sufficiently complementary to the desired nucleic acid sequences, as to hybridize with them and synthesize extension products.

Primers are oligonucleotides, natural or synthetic, which are capable of acting as points of initiation for DNA synthesis when placed under conditions in which synthesis of a primer extension product which is
20 complementary to a nucleic acid strand is induced, that is, in the presence of four different nucleotide triphosphates and thermostable enzymes in an appropriate buffer and at a suitable temperature.

PCR amplification was carried out on the Taq Pol DNA of i) essentially as described by Saiki and others, in an Ericomp thermocycler. Primers were designed based upon the published sequence of the Taq Pol gene (Lawyer and others). Amplification mixtures contained approximately 100 ng of *T. aquaticus* DNA,
25 1 µM of each of the two primers, 200 µM each of dATP, dGTP, dCTP and dTTP, and 2 units of Taq Pol in a volume of 0.05 mL. The mixtures were heated to 97 °C for 10 seconds, annealed at 40 °C for thirty seconds, and extended at 72 °C for 5 minutes for 5 cycles. For the subsequent 20 cycles, the annealing temperature was raised to 55 °C and the extension time reduced to 3 minutes. Finally, the mixtures were incubated at 72 °C for 15 minutes to maximize the amount of fully double-stranded product. The entire PCR
30 reaction mixture was fractionated on a 1.0% agarose gel and the 2.5 kb Taq polymerase gene was cut out and extracted. DNA fragments were isolated from agarose gels using a "freeze-squeeze technique". Agarose slices were minced, frozen on dry ice, and rapidly thawed at 37 °C for five minutes. The slurry was filtered by centrifugation through a Millipore 0.45 mm Durapore membrane. The filtrate was extracted once with water saturated phenol, once with phenol-chloroform (1:1), and once with chloroform. The DNA was
35 recovered by ethanol precipitation.

Incorporating Restriction Sites: To allow excision and recovery of the Taq Pol gene during PCR and also to afford convenient cloning of the Taq Pol gene into an expression vector, two restriction sites were introduced at the 5' ends of both strands of the gene. More specifically, one restriction site was introduced adjacent to and upstream from the start (ATG) codon and the other restriction site was introduced adjacent
40 to and downstream from the stop (TGA) codon (SEQ ID NOS: 6 & 7). The nucleotides forming the restriction sites were included on the synthetic primer used in the PCR. In the examples disclosed herein, the nucleotide sequence GAATTC, which forms EcoR1 restriction site was included on the primers.

Other restriction sites may be used in the practice of this invention provided that 1) the expression vector has a corresponding site where the Taq DNA is to be ligated, 2) the restriction site does not occur
45 within the Taq Pol gene.

As shown in Figure 1, EcoR1 is one of several restriction sites in pSCW562. Other exemplary restriction sites are XbaI and SphI. Of course, expression vectors having other restriction sites would provide still more potential restriction sites which would be useful in the practice of this invention.

When digested with the appropriate enzyme, these restriction sites form sticky ends which can be
50 conveniently ligated to correspondingly digested restriction sites on the expression vector. The restriction sites do not affect the amino acid sequence of Taq Pol.

Alternative Method: In lieu of the PCR technique described above, the native Taq Pol gene may alternatively be provided by conventionally cloning the gene. In that event, the restriction sites may be introduced by site directed mutagenesis. The end results of either procedure are indistinguishable.

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iii. Ligating DNA Fragments into a Vector

The DNA from step ii) is then ligated to a suitable expression vector. The vector chosen for cloning was pSCW562, which contains an EcoR1 site 11 base pairs downstream of the ribosome binding site and the strong tac (trp-lac hybrid) promoter (Figure 1). The Taq Pol gene does not contain any EcoR1 sites, so the PCR primers were designed with EcoR1 sites near their 5' ends (step ii)) to allow direct cloning into the EcoR1 site of pSCW562.

In addition to the EcoR1 site, vector pSCW562 contains 1) a phage origin of replication (F_1), 2) a plasmid origin of replication (ORI), 3) an antibiotic resistance marker (AMP), and 4) a transcription termination sequence downstream of the restriction sites. This plasmid was constructed using techniques well known in the art of recombinant DNA as taught in Maniatis and others, Molecular Cloning: A Laboratory Manual, Cold Spring Harbor, New York (1982). However, this particular plasmid is not critical to the invention. Any vector containing an appropriate promoter and restriction sites will be useful in this method.

The EcoR1-digested PCR product from Step ii) was fractionated in a 1% agarose gel and eluted. The vector, pSCW562, was digested overnight with EcoR1 (10 units/ μ g) and treated with calf intestinal alkaline phosphatase (1 unit/ μ g), extracted with phenol/chloroform, ethanol precipitated, and resuspended in TE. Approximately 200 ng of the prepared vector was mixed with 500 ng of purified PCR product and ligated for 18 hours in 50 mM TrisHCl, pH 7.8, 10 mM MgCl₂, 20 mM dithiothreitol, 1mM ATP, with 0.5 Weiss units of T4 DNA ligase in a volume of 20 μ L.

iv. Using Site-Directed Mutagenesis to Change the Nucleotide Sequence of the Native Taq Pol Gene

Site-directed mutagenesis is a method of altering the nucleotide sequence of a DNA fragment by specifically substituting, inserting or deleting selected nucleotides within the sequence to be altered. The method involves priming in vitro DNA synthesis with chemically synthesized nucleotides that carry a nucleotide mismatch with the template sequence. The synthetic oligonucleotide primes DNA synthesis and is itself incorporated into the resulting heteroduplex molecule. After transformation of host cells, this heteroduplex gives rise to homoduplexes whose sequences carry the mutagenic nucleotides. Mutant clones are selected by screening procedures well known in the art such as nucleic acid hybridization with labelled probes and DNA sequencing.

Using site-directed mutagenesis, we constructed mutant genes for Taq polymerase wherein the sequence of the first thirty nucleotide bases in the native gene which code for the first ten amino acids in the mature native protein, was changed

A) by substituting therefor a modified nucleotide sequence selected from the group consisting of:

Example 1 - SEQ ID NO: 2:

ATG CGT GGT ATG CTG CCT CTG TTT GAG CCG AAG , 33

Example 2 - SEQ ID NO: 3:

ATG CGT GGG ATG CTG CCC CTC TTT GAG CCC AAG , and 33

Example 3 - SEQ ID NO: 4:

ATG GAC TAC AAG GAC GAC GAT GAC AAG CGT GGT ATG 36

CTG CCC CTC TTT GAG CCC AAG , 57

or, Example 4,

B) by inserting between the start codon (ATG) for the first amino acid of the mature native protein and the codon, (AGG) for the second amino acid of the mature native protein, the sequence:

SEQ ID NO: 13:

GAC TAC AAG GAC GAC GAT GAC AAG .

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In the examples above, bases that are changed are highlighted in bold type. The effect that these changes have on polymerase activity is shown in Table I. The above examples are offered by way of illustration only and are by no means intended to limit the scope of the claimed invention.

10 In these examples all gene modifications were carried out by site-directed mutagenesis. However, alternative methods are known in the art which would give the same results. For example, the changes to the Taq Pol gene described above could have been incorporated directly into the gene during amplification (PCR) by appropriately designing the upstream oligonucleotide primer to include the nucleotide sequences of the invention.

15 Another alternative would be to incorporate unique restriction sites bracketing the first ten codons of the gene. This would allow removal of the sequences encoding the amino terminus by restriction endonuclease cleavage and replacement using a double stranded synthetic fragment. Either of these methods could be used to accomplish the nucleotide changes set forth above.

20 Site-directed mutagenesis was carried out essentially as described by Kunkel and others, Rapid and Efficient Site-specific Mutagenesis without Phenotypic Selection, Methods Enzymol, 15:367-382, (1987), using a kit obtained from Bio Rad. Single-stranded plasmid DNA was prepared by infecting early exponential phase cultures of CJ236 (carrying pTaq1) with R408 at a multiplicity of infection of approximately 10-20. After overnight growth at 37°C, the cells were removed by centrifugation and the phage precipitated by addition of polyethylene glycol to 5% and NaCl to 0.5 M. The phage were pelleted by centrifugation and the DNA isolated by phenol-chloroform extraction and ethanol precipitation. The 25 mutagenic oligonucleotides were phosphorylated with T4 polynucleotide kinase and 9 pmol of each was annealed to approximately 3 pmol of single-stranded plasmid DNA. The annealed mixture was extended with T4 DNA polymerase, ligated, and transformed into DH5 α or JM103. Plasmid DNA was isolated from the transformants by rapid boiling (Holmes and Quigley, A Rapid Boiling Method for the Preparation of Bacterial Plasmids, Anal. Biochem. 114:193-199, 1981) and digested with EcoRI to identify clones that had 30 undergone mutagenesis.

v. Screening for Vectors with the Taq Pol Gene

To verify that the clones of iv) were carrying the desired Taq Pol gene, clones were lifted on to 35 nitrocellulose filters and identified as Taq Pol transformants by colony hybridization.

Colony Hybridization: This technique identifies a specific nucleic acid sequence by creating conditions for single strands of the specific nucleic acid sequence to base pair (hybridize) with a complementary radioactive single stranded nucleic acid fragments (probes). Double-stranded regions form where the two types of DNA have complementary nucleotide sequences and are detected by their radioactivity.

40 Colonies containing the Taq Pol fragment were identified by hybridization with an internal oligonucleotide:

SEQ ID NO: 15:

GTGGTCTTTG ACGCCAAG,

45

labelled with ³²P at the 5' end with T4 polynucleotide kinase. Colony hybridizations were performed as described in Maniatis and others, supra in 5X SSPE [1XSSPE in 10 mM sodium phosphate, pH 7.0, 0.18 M 50 NaCl, 1 mM EDTA], 0.1% sodium lauroyl sarcosine, 0.02% SDS, 0.5% blocking agent (Boehringer-Mannheim) containing approximately 5 ng per mL ³²P labelled oligonucleotide. Hybridization was conducted at 42°C for 4-18 hours. The filters were washed in 2X SSPE, 0.1% SDS at room temperature three times, followed by a stringent wash at 42°C in the same solution. Positive colonies were identified by autoradiography.

55 Sequence Analysis: To ascertain whether or not the Taq Pol DNA was incorporated in the correct orientation, DNA sequence analysis was performed on alkaline denatured supercoiled DNA as described by Zhang and others. Double Stranded DNA sequencing as a Choice for DNA Sequencing, Nucleic Acids Research 16:1220 (1988), using a Sequenase™ kit from U.S. Biochemicals and a (³⁵S)dATP. Typically, 1.0

5 μ L of supercoiled, CsCl-banded DNA was denatured in 20 μ L of 0.2 M NaOH, 0.2 mM EDTA for 5 minutes. The solution was neutralized with 2 μ L of 2 M ammonium acetate (pH 4.6) and precipitated with 60 mL of ethanol. The mixture was centrifuged for 10 minutes, washed once with 80% ethanol, dried for 10 minutes and resuspended in 7 mL of H₂O. After addition of 5 ng of primer and 2 μ L of 5X buffer, the samples were
 10 heated to 65°C and allowed to cool to 37°C over 30-45 minutes. The sequencing reactions were then performed as directed by the supplier. The reactions were then performed as directed by the supplier. The reactions were electrophoresed on 6% sequencing gels, occasionally utilizing a sodium acetate salt gradient to improve resolution near the bottom of the gel (Sheen and others, Electrolyte Gradient Gels for DNA Sequencing, Bio Techniques 6:942-944, 1989). Alternatively, plasmid DNA prepared by the rapid boiling or
 10 alkaline miniprep procedures was used for sequencing after extraction with phenol-chloroform and ethanol precipitation, although with some reduced reliability.

Step B - Transfecting Host Cells with the Vector of A)

15 The vector of step A) is used to transfect a suitable host and the transformed host is cultured under favorable conditions for growth. Prokaryotic hosts are in general the most efficient and convenient in genetic engineering techniques and are therefore preferred for the expression of Taq polymerase. Prokaryotes most frequently are represented by various strains of *E. coli* such as DH5 α and JM103, the strains used in the examples below. However, other microbial strains may also be used, as long as the strain selected as host
 20 is compatible with the plasmid vector with which it is transformed. Compatibility of host and plasmid/vector means that the host faithfully replicates the plasmid/vector DNA and allows proper functioning of the above controlling elements. In our system, DH5 α and JM103 are compatible with pSCW562.

25 Five mL of the ligation mixture of Step B were mixed with 0.1 μ L of DH5 α or JM103 cells made competent by CaCl₂ treatment as described by Cohen and others, Proc. National Academy of Science, USA, 69:2110 (1972). After incubation on ice for 15-30 minutes, the mixture was incubated at 42°C for 90 seconds. After the heat shock, one mL of LB medium was added and the cells were incubated for one hour at 37°C.

30 Selection of Transformants: After the one-hour incubation, aliquots of the incubated mixture were spread on LB agar plates containing 50 μ g/mL ampicillin and incubated at 37°C for 18 hours. Only transformed *E. coli* carrying the AMP (marker) gene can grow on this medium. To select transformants that were also carrying the Taq Pol gene in correct orientation, colony hybridization and sequence analysis were done using techniques already described above.

Step C - Culturing the Transformed Hosts

35 *E. coli* transformants verified as containing the Taq Pol gene in the correct orientation, were cultured in 40 mL of LB broth at 37°C to mid-log phase and where appropriate, were induced with 1 mM isopropyl- β -D-thiogalactoside (IPTG). The cells were allowed to grow for either an additional two hours or overnight, and were harvested by centrifugation. The cells were resuspended in 0.25 mL of 50 mM TrisHCl, pH 7.5, 1 mM
 40 EDTA, 0.5 μ g/mL leupeptin, 2.4 mM phenylmethylsulfonyl fluoride and sonicated. The lysate was diluted with 0.25 mL of 10 mM TrisHCl, pH 8.0, 50 mM KCl, 0.5% Tween 20, 0.5% NP-40 and heated to 74°C for 20 minutes. After cooling on ice for 15 minutes, the debris was removed by centrifugation for 10 minutes at 4°C. Aliquots of the supernatant fraction were assayed for DNA polymerase activity using activated salmon sperm DNA as the substrate.

45 DNA Polymerase Assay: This assay is based on the ability of DNA polymerases to fill in single strand gaps made in double stranded DNA. It uses the single strand gaps as templates and the free 3' hydroxyl group at the border of the single strand gap as the primer at which it begins synthesis. Specifically, 5 μ L of enzyme preparation was incubated for 10 minutes at 74°C in a total of 50 μ L with the following: 25 mM Tris(hydroxymethyl)methyl-3-amino-propane sulfonic acid (TAPS) (pH 9.8 at 22°C), 50 mM KCl, 1 mM 2-
 50 mercaptoethanol, 2 mM MgCl₂, 0.30 mg/mL activated salmon testes DNA, 0.2 mM of each dCTP, dGTP, dTTP, and 0.1 mM (200 nCi/nmol) [8-³H]dATP. The reaction was stopped by the addition of 100 μ L of 0.15 M sodium pyrophosphate, 0.105 M sodium EDTA, pH 8.0, followed by the addition of ice cold 10% trichloroacetic acid (TCA). It was then kept on ice for 15-30 minutes prior to being vacuum filtered on a prewet 25 mm Whatman glass fiber filters (GFC) filter disk. The precipitated reaction product was washed
 55 free of unincorporated ³H on the filter with a total of 12 mL of ice cold 10% TCA followed by a total of 12 mL of ice cold 95% ethanol. Filters were vacuum dried, then air dried, and then counted directly in a scintillation fluid. Enzyme preparations that required diluting were diluted with a solution of 10 mM Tris, 50

mM KCl, 10 mM MgCl₂, 1.0 mg/mL gelatin, 0.5% nonidet P40, 0.5% Tween 20, 1 mM 2-mercaptoethanol, pH 8.0. One unit of activity is the amount of enzyme required to incorporate 10 nmol of total nucleotide in 30 min at 74 °C; adenine constitutes approximately 29.7% of the total bases in salmon sperm DNA.

Salmon testes DNA (Sigma type III; product #D1626) was dissolved to 1.3 mg/mL in TM buffer (10 mM Tris, 5 mM MgCl₂, pH 7.2) and stirred slowly for 24 hours at 4 °C. It was then diluted 2.5 fold with TM buffer and made 0.3 M in NaCl prior to extracting at room temperature with an equal volume of phenol:chloroform (1:1::vol:vol; phenol saturated with TM buffer). The mixture was centrifuged at 2700 x g for 5 minutes at room temperature to aid separation of the phases, the aqueous phase was collected and extracted with an equal volume of chloroform. The mixture was centrifuged as above and the aqueous phase again collected. The activated DNA in the aqueous phase was precipitated with two volumes of 95% ethanol at -20 °C; the precipitated mixture was kept at -20 °C for 12-18 hours. The precipitated DNA was collected by centrifuging at 13,700 x g for 30 minutes at 2 °C. The pellet was dried with a stream of nitrogen gas and then redissolved 3-6 mg/mL with TE (10 mM Tris, 1 mM EDTA, pH 7.5) with slow rocking for 12-18 hours at room temperature. The solution was dialyzed against TE and then adjusted to the proper concentration by checking the absorbance at 260 nm. Aliquots (0.5-1.0 mL) were stored at -20 °C; for use, one vial was thawed and then kept at 4 °C rather than refreezing.

5. Results of Polymerase Assay

The results of the Taq Pol assay are shown in Table I. Vector pTaq1 carries SEQ ID NO:1 which is the native Taq Pol sequence, while the other four plasmids carry sequences which are altered in accordance with the invention as described above.

Table I shows, unexpectedly, that pTaq3 (SEQ ID NO: 2) expressed Taq Pol activity up to 200 times that of pTaq1; pTaq4 (SEQ ID NO: 3) had about 10 times the activity of pTaq1; pTaq5 (SEQ ID NO: 4) was about 10 - 50 times greater than pTaq1, depending on the experiment, and pTaq6 (SEQ NO: 5) was at least 10 times as great as pTaq1 (SEQ ID NO: 1). These results are unexpected.

The short nucleotide sequences in the Sequence Listing represent sequence changes in the first 30 nucleotides of the native gene. It is to be understood that these sequences represent only a small fraction of the complete Taq Pol gene which in its entirety contains over 2,000 nucleotides.

T A B L E I
(Units/mg of protein)

5	Host Strain:							
	Time of							
	Harvest:	DH5 α	DH5 α	JM103	JM103	JM103	JM103	JM103
	Induction	O/N	O/N	2 Hrs.	2 Hrs.	O/N	2 Hrs.	2 Hrs.
10	Plasmid	-	+	+	+	+	-	+
	<u>SEC ID NO.1</u>	40	90	100	270	1030	60	180
	pTaq1							
15	<u>SEC ID NO.2</u>	7290	19240	4150	4510	27420	11400	21810
	pTaq3							
	<u>SEC ID NO.3</u>	470	1050	1080	1570	5080	900	2360
20	pTaq4							
	<u>SEC ID NO.4</u>	ND	ND	6060	4610	14190	3500	10700
	pTaq5							
25	<u>SEC ID NO.5</u>	2486	7644	ND	ND	ND	ND	NT
	pTaq6							

ND = not determined

ON = overnight

+ = induction

- = no induction

Table I - Assay of thermostable DNA polymerase activity encoded by the various expression plasmids. Polymerase activity is interpreted as a reflection of gene expression and polymerase production.

SEQUENCE IDENTIFICATION

- (1) GENERAL INFORMATION:
 - (i) APPLICANT: Sullivan, Mark Alan
 - (ii) TITLE OF INVENTION: Increased Production of Thermus aquaticus DNA Polymerase in E. coli.
 - (iii) NUMBER OF SEQUENCES: 14
 - (iv) CORRESPONDENCE ADDRESS:
 - (A) ADDRESSEE: Eastman Kodak Company, Patent Department
 - (B) STREET: 343 State Street
 - (C) CITY: Rochester
 - (D) STATE: New York
 - (E) COUNTRY: U.S.A.
 - (F) ZIP: 14650-2201
 - (v) COMPUTER READABLE FORM:
 - (A) MEDIUM TYPE: Diskette, 3.5 inch, 800 Kb storage
 - (B) COMPUTER: Apple Macintosh
 - (C) OPERATING SYSTEM: Macintosh 6.0
 - (D) SOFTWARE: WriteNow
 - (vi) CURRENT APPLICATION DATA:
 - (A) APPLICATION NUMBER:
 - (B) FILING DATE:
 - (C) CLASSIFICATION:
 - (vii) PRIOR APPLICATION DATA: None
 - (viii) ATTORNEY/AGENT INFORMATION:
 - (A) NAME: Wells, Doreen M.
 - (B) REGISTRATION NUMBER: 34,278
 - (C) REFERENCE/DOCKET NUMBER: 58374D-W1100
 - (ix) TELECOMMUNICATION INFORMATION:
 - (A) TELEPHONE: (716) 477-0554
 - (B) TELEFAX: (716) 477-4646
- (2) INFORMATION FOR SEQ ID NO: 1:
 - (i) SEQUENCE CHARACTERISTICS
 - (A) LENGTH: 2499
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: double
 - (D) TOPOLOGY: linear
 - (ii) MOLECULE TYPE: genomic DNA
 - (iii) HYPOTHETICAL: no
 - (iv) ANTI-SENSE: no
 - (v) ORIGINAL SOURCE:
 - (A) ORGANISM: Thermus aquaticus
 - (B) ISOLATE: YT1, ATCC 25104
 - (vii) IMMEDIATE SOURCE: amplified from genomic DNA
 - (ix) FEATURE:
 - (A) NAME/KEY: peptide
 - (B) LOCATION: 1-2496
 - (C) IDENTIFICATION METHOD: comparison to sequence in GenBank, Accession number J04639.
 - (x) PUBLICATION INFORMATION:

(A) AUTHORS: Lawyer, F.C., Stoffel, S., Saiki, R.K., Myambo, K.,
Drummond, R., Gelfand, D.H.

(B) TITLE: Isolation, characterization and expression in
Escherichia coli of the DNA polymerase gene from Thermus aquaticus.

(C) JOURNAL: Journal of Biological Chemistry

(D) VOLUME: 264

(E) ISSUE: 11

(F) PAGES: 6427-6437

(G) DATE: 15-Apr-1989

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1 :

5	ATG AGG GGG ATG CTG CCC CTC TTT GAG CCC AAG GGC CGG GTC CTC	45
	Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu	
	1 5 10 15	
15	CTG GTG GAC GGC CAC CAC CTG GCC TAC CGC ACC TTC CAC GCC CTG	90
	Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu	
	20 25 30	
20	AAG GGC CTC ACC ACC AGC CGG GGG GAG CCG GTG CAG GCG GTC TAC	135
	Lys Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr	
	35 40 45	
25	GGC TTC GCC AAG AGC CTC CTC AAG GCC CTC AAG GAG GAC GGG GAC	180
	Gly Phe Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp	
	50 55 60	
30	GCG GTG ATC GTG GTC TTT GAC GCC AAG GCC CCC TCC TTC CGC CAC	225
	Ala Val Ile Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His	
	65 70 75	
35	GAG GCC TAC GGG GGG TAC AAG GCG GGC CGG GCC CCC ACG CCG GAG	270
	Glu Ala Tyr Gly Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu	
	80 85 90	
40	GAC TTT CCC CGG CAA CTC GCC CTC ATC AAG GAG CTG GTG GAC CTC	315
	Asp Phe Pro Arg Gln Leu Ala Leu Ile Lys Glu Leu Val Asp Leu	
	95 100 105	
45	CTG GGG CTG GCG CGC CTC GAG GTC CCG GGC TAC GAG GCG GAC GAC	360
	Leu Gly Leu Ala Arg Leu Glu Val Pro Gly Tyr Glu Ala Asp Asp	
	110 115 120	
50	GTC CTG GCC AGC CTG GCC AAG AAG GCG GAA AAG GAG GGC TAC GAG	405
	Val Leu Ala Ser Leu Ala Lys Lys Ala Glu Lys Glu Gly Tyr Glu	
	125 130 135	
55	GTC CGC ATC CTC ACC GCC GAC AAA GAC CTT TAC CAG CTC CTT TCC	450
	Val Arg Ile Leu Thr Ala Asp Lys Asp Leu Tyr Gln Leu Leu Ser	
	140 145 150	
60	GAC CGC ATC CAC GTC CTC CAC CCC GAG GGG TAC CTC ATC ACC CCG	495
	Asp Arg Ile His Val Leu His Pro Glu Gly Tyr Leu Ile Thr Pro	
	155 160 165	

	GCC TGG CTT TGG GAA AAG TAC GGC CTG AGG CCC GAC CAG TGG GCC	540
	Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro Asp Gln Trp Ala	
	170 175 180	
5	GAC TAC CGG GCC CTG ACC GGG GAC GAG TCC GAC AAC CTT CCC GGG	585
	Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp Asn Leu Pro Gly	
	185 190 195	
10	GTC AAG GGC ATC GGG GAG AAG ACG GCG AGG AAG CTT CTG GAG GAG	630
	Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu Leu Glu Glu	
	200 205 210	
15	TGG GGG AGC CTG GAA GCC CTC CTC AAG AAC CTG GAC CGG CTG AAG	675
	Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg Leu Lys	
	215 220 225	
20	CCC GCC ATC CGG GAG AAG ATC CTG GCC CAC ATG GAC GAT CTG AAG	720
	Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu Lys	
	230 235 240	
25	CTC TCC TGG GAC CTG GCC AAG GTG CGC ACC GAC CTG CCC CTG GAG	765
	Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu	
	245 250 255	
30	GTG GAC TTC GCC AAA AGG CGG GAG CCC GAC GGG GAG GGG CTT AGG	810
	Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Gly Leu Arg	
	260 265 270	
35	GCC TTT CTG GAG AGG CTT GAG TTT GGC AGC CTC CTC CAC GAG TTC	855
	Ala Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe	
	275 280 285	
40	GGC CTT CTG GAA AGC CCC AAG GCC CTG GAG GAG GCC CCC TGG CCC	900
	Gly Leu Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro	
	290 295 300	
45	CCG CCG GAA GGG GCC TTC GTG GGC TTT GTG CTT TCC CGC AAG GAG	945
	Pro Pro Glu Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu	
	305 310 315	
50	CCC ATG TGG GCC GAT CTC CTC GCC CTG GCC GCC GCC AGG GGG GGC	990
	Pro Met Trp Ala Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly	
	320 325 330	
55	CGG GTC CAC CGG GCC CCC GAG CCT TAT AAA GCC CTC AGG GAC CTG	1035
	Arg Val His Arg Ala Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu	
	335 340 345	
60	AAG GAG GCG CGG GGG CTT CTC GCC AAA GAC CTG AGC GTT CTG GCC	1080
	Lys Glu Ala Arg Gly Leu Leu Ala Lys Asp Leu Ser Val Leu Ala	
	350 355 360	

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	CTG	AGG	GAA	GGC	CTT	GGC	CTC	CCG	CCC	GGC	GAC	GAC	CCC	ATG	CTC	1125
	Leu	Arg	Glu	Gly	Leu	Gly	Leu	Pro	Pro	Gly	Asp	Asp	Pro	Met	Leu	
					365					370					375	
5	CTC	GCC	TAC	CTC	CTG	GAC	CCT	TCC	AAC	ACC	ACC	CCC	GAG	GGG	GTG	1170
	Leu	Ala	Tyr	Leu	Leu	Asp	Pro	Ser	Asn	Thr	Thr	Pro	Glu	Gly	Val	
					380					385					390	
10	GCC	CGG	CGC	TAC	GGC	GGG	GAG	TGG	ACG	GAG	GAG	GCG	GGG	GAG	CGG	1215
	Ala	Arg	Arg	Tyr	Gly	Gly	Glu	Trp	Thr	Glu	Glu	Ala	Gly	Glu	Arg	
					395					400					405	
15	GCC	GCC	CTT	TCC	GAG	AGG	CTC	TTC	GCC	AAC	CTG	TGG	GGG	AGG	CTT	1260
	Ala	Ala	Leu	Ser	Glu	Arg	Leu	Phe	Ala	Asn	Leu	Trp	Gly	Arg	Leu	
					410					415					420	
20	GAG	GGG	GAG	GAG	AGG	CTC	CTT	TGG	CTT	TAC	CGG	GAG	GTG	GAG	AGG	1305
	Glu	Gly	Glu	Glu	Arg	Leu	Leu	Trp	Leu	Tyr	Arg	Glu	Val	Glu	Arg	
					425					430					435	
25	CCC	CTT	TCC	GCT	GTC	CTG	GCC	CAC	ATG	GAG	GCC	ACG	GGG	GTG	CGC	1350
	Pro	Leu	Ser	Ala	Val	Leu	Ala	His	Met	Glu	Ala	Thr	Gly	Val	Arg	
					440					445					450	
30	CTG	GAC	GTG	GCC	TAT	CTC	AGG	GCC	TTG	TCC	CTG	GAG	GTG	GCC	GAG	1395
	Leu	Asp	Val	Ala	Tyr	Leu	Arg	Ala	Leu	Ser	Leu	Glu	Val	Ala	Glu	
					455					460					465	
35	GAG	ATC	GCC	CGC	CTC	GAG	GCC	GAG	GTC	TTC	CGC	CTG	GCC	GGC	CAC	1440
	Glu	Ile	Ala	Arg	Leu	Glu	Ala	Glu	Val	Phe	Arg	Leu	Ala	Gly	His	
					470					475					480	
40	CCC	TTC	AAC	CTC	AAC	TCC	CGG	GAC	CAG	CTG	GAA	AGG	GTC	CTC	TTT	1485
	Pro	Phe	Asn	Leu	Asn	Ser	Arg	Asp	Gln	Leu	Glu	Arg	Val	Leu	Phe	
					485					490					495	
45	GAC	GAG	CTA	GGG	CTT	CCC	GCC	ATC	GGC	AAG	ACG	GAG	AAG	ACC	GGC	1530
	Asp	Glu	Leu	Gly	Leu	Pro	Ala	Ile	Gly	Lys	Thr	Glu	Lys	Thr	Gly	
					500					505					510	
50	AAG	CGC	TCC	ACC	AGC	GCC	GCC	GTC	CTG	GAG	GCC	CTC	CGC	GAG	GCC	1575
	Lys	Arg	Ser	Thr	Ser	Ala	Ala	Val	Leu	Glu	Ala	Leu	Arg	Glu	Ala	
					515					520					525	
55	CAC	CCC	ATC	GTG	GAG	AAG	ATC	CTG	CAG	TAC	CGG	GAG	CTC	ACC	AAG	1620
	His	Pro	Ile	Val	Glu	Lys	Ile	Leu	Gln	Tyr	Arg	Glu	Leu	Thr	Lys	
					530					535					540	
60	CTG	AAG	AGC	ACC	TAC	ATT	GAC	CCC	TTG	CCG	GAC	CTC	ATC	CAC	CCC	1665
	Leu	Lys	Ser	Thr	Tyr	Ile	Asp	Pro	Leu	Pro	Asp	Leu	Ile	His	Pro	
					545					550					555	

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	AGG	ACG	GGC	CGC	CTC	CAC	ACC	CGC	TTC	AAC	CAG	ACG	GCC	ACG	GCC	1710
	Arg	Thr	Gly	Arg	Leu	His	Thr	Arg	Phe	Asn	Gln	Thr	Ala	Thr	Ala	
					560					565					570	
5	ACG	GGC	AGG	CTA	AGT	AGC	TCC	GAT	CCC	AAC	CTC	CAG	AAC	ATC	CCC	1755
	Thr	Gly	Arg	Leu	Ser	Ser	Ser	Asp	Pro	Asn	Leu	Gln	Asn	Ile	Pro	
					575					580					585	
10	GTC	CGC	ACC	CCG	CTT	GGG	CAG	AGG	ATC	CGC	CGG	GCC	TTC	ATC	GCC	1800
	Val	Arg	Thr	Pro	Leu	Gly	Gln	Arg	Ile	Arg	Arg	Ala	Phe	Ile	Ala	
					590					595					600	
15	GAG	GAG	GGG	TGG	CTA	TTG	GTG	GCC	CTG	GAC	TAT	AGC	CAG	ATA	GAG	1845
	Glu	Glu	Gly	Trp	Leu	Leu	Val	Ala	Leu	Asp	Tyr	Ser	Gln	Ile	Glu	
					605					610					615	
	CTC	AGG	GTG	CTG	GCC	CAC	CTC	TCC	GGC	GAC	GAG	AAC	CTG	ATC	CGG	1890
	Leu	Arg	Val	Leu	Ala	His	Leu	Ser	Gly	Asp	Glu	Asn	Leu	Ile	Arg	
					620					625					630	
20	GTC	TTC	CAG	GAG	GGG	CGG	GAC	ATC	CAC	ACG	GAG	ACC	GCC	AGC	TGG	1935
	Val	Phe	Gln	Glu	Gly	Arg	Asp	Ile	His	Thr	Glu	Thr	Ala	Ser	Trp	
					635					640					645	
25	ATG	TTC	GGC	GTC	CCC	CGG	GAG	GCC	GTG	GAC	CCC	CTG	ATG	CGC	CGG	1980
	Met	Phe	Gly	Val	Pro	Arg	Glu	Ala	Val	Asp	Pro	Leu	Met	Arg	Arg	
					650					655					660	
30	GCG	GCC	AAG	ACC	ATC	AAC	TTC	GGG	GTC	CTC	TAC	GGC	ATG	TCG	GCC	2025
	Ala	Ala	Lys	Thr	Ile	Asn	Phe	Gly	Val	Leu	Tyr	Gly	Met	Ser	Ala	
					665					670					675	
	CAC	CGC	CTC	TCC	CAG	GAG	CTA	GCC	ATC	CCT	TAC	GAG	GAG	GCC	CAG	2070
	His	Arg	Leu	Ser	Gln	Glu	Leu	Ala	Ile	Pro	Tyr	Glu	Glu	Ala	Gln	
					680					685					690	
35	GCC	TTC	ATT	GAG	CGC	TAC	TTT	CAG	AGC	TTC	CCC	AAG	GTG	CGG	GCC	2115
	Ala	Phe	Ile	Glu	Arg	Tyr	Phe	Gln	Ser	Phe	Pro	Lys	Val	Arg	Ala	
					695					700					705	
40	TGG	ATT	GAG	AAG	ACC	CTG	GAG	GAG	GGC	AGG	AGG	CGG	GGG	TAC	GTG	2160
	Trp	Ile	Glu	Lys	Thr	Leu	Glu	Glu	Gly	Arg	Arg	Arg	Gly	Tyr	Val	
					710					715					720	
	GAG	ACC	CTC	TTC	GGC	CGC	CGC	CGC	TAC	GTG	CCA	GAC	CTA	GAG	GCC	2205
	Glu	Thr	Leu	Phe	Gly	Arg	Arg	Arg	Tyr	Val	Pro	Asp	Leu	Glu	Ala	
					725					730					735	
45	CGG	GTG	AAG	AGC	GTG	CGG	GAG	GCG	GCC	GAG	CGC	ATG	GCC	TTC	AAC	2250
	Arg	Val	Lys	Ser	Val	Arg	Glu	Ala	Ala	Glu	Arg	Met	Ala	Phe	Asn	
					740					745					750	

5 ATG CCC GTC CAG GGC ACC GCC GCC GAC CTC ATG AAG CTG GCT ATG 2295
 Met Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met 765
 755 760 765
 10 GTG AAG CTC TTC CCC AGG CTG GAG GAA ATG GGG GCC AGG ATG CTC 2340
 Val Lys Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu 780
 770 775 780
 15 CTT CAG GTC CAC GAC GAG CTG GTC CTC GAG GCC CCA AAA GAG AGG 2385
 Leu Gln Val His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg 795
 785 790 795
 20 GCG GAG GCC GTG GCC CGG CTG GCC AAG GAG GTC ATG GAG GGG GTG 2430
 Ala Glu Ala Val Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val 810
 800 805 810
 25 TAT CCC CTG GCC GTG CCC CTG GAG GTG GAG GTG GGG ATA GGG GAG 2475
 Tyr Pro Leu Ala Val Pro Leu Glu Val Glu Val Gly Ile Gly Glu 825
 815 820 825
 30 GAC TGG CTC TCC GCC AAG GAG TGA 2499
 Asp Trp Leu Ser Ala Lys Glu End 830

25 (3) INFORMATION FOR SEQ ID NO: 2:
 (i) SEQUENCE CHARACTERISTICS
 (A) LENGTH: 33
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear
 30 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2 :

35 ATG CGT GGT ATG CTG CCT CTG TTT GAG CCG AAG 33
 Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys
 1 5 10

40 (4) INFORMATION FOR SEQ ID NO:3:
 (i) SEQUENCE CHARACTERISTICS
 (A) LENGTH: 33
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear
 45 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

50 ATG CGT GGT ATG CTG CCT CTG TTT GAG CCG AAG 33
 Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys
 1 5 10

50

55

(5) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 57
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

10 ATG GAC TAC AAG GAC GAC GAT GAC AAG CGT GGT ATG 36
 Met Asp Tyr Lys Asp Asp Asp Asp Lys Arg Gly Met
 1 5 10

15 CTG CCC CTC TTT GAG CCC AAG 57
 Leu Pro Leu Phe Glu Pro Lys
 15

(6) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 57
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

25 ATG GAC TAC AAG GAC GAC GAT GAC AAG 27
 Met Asp Tyr Lys Asp Asp Asp Asp Lys
 1 5

30 AGG GGG ATG CTG CCC CTC TTT GAG CCC AAG 57
 Arg Gly Met Leu Pro Leu Phe Glu Pro Lys
 10 15

(7) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 20
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

40 GAATTC ATG AGG GGG ATG CT 20

45

50

55

(8) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 23
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

GGTGAAT TCA CTC CTT GGC GGA

23

(9) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 24
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

GAC TAC AAG GAC GAC GAT GAC AAG
Asp Tyr Lys Asp Asp Asp Asp Lys
1 5

24

(10) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 8 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

Met Asp Tyr Lys Asp Asp Asp Asp Lys
1 5

(11) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 18
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

GTGGTCTTTG ACGCCAAG

18

(12) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 59
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

AGGGGCAGCA TACCACGCTT GTCATCGTCG TCCTTG TAGT CCATAATTCT 50
GTTTCCTGT 59

(13) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 59
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 12:

AGGGGCAGCA TCCCCCTCTT GTCATCGTCG TCCTTG TAGT CCATGAATTC 50
TGTTTCCTGT 60

(14) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 48
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 13:

GCCCTTCGGC TCAAACAGTG GCAGCATACC ACGCATAATT CTGTTTCC 48

(15) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS

- (A) LENGTH: 53
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 14:

CGGCCCTTG GCTCAAAGAG GGGCAGCATC CCACGCATGA ATTCCTGTTT 50
CCT 53

Claims

1. A gene for Taq polymerase wherein the sequence of the first thirty nucleotide bases in the native gene which code for the first ten amino acids in the mature native protein, has been changed

A) by substituting therefor a modified nucleotide sequence selected from the group consisting of:

SEQ ID NO: 2:

ATG CGT GGT ATG CTG CCT CTG TTT GAG CCG AAG , 33

5

SEQ ID NO: 3:

ATG CGT GGG ATG CTG CCC CTC TTT GAG CCC AAG , and 33

10

SEQ ID NO: 4:

ATG GAC TAC AAG GAC GAC GAT GAC AAG CGT GGT ATG 36
CTG CCC CTC TTT GAG CCC AAG , 57

15

or

B) by inserting between the start codon (ATG) of the mature native protein and the codon, (AGG) for the second amino acid of the mature native protein, the sequence:

20

SEQ ID NO: 5:

GAC TAC AAG GAC GAC GAT GAC AAG . 24

25

2. The gene of Claim 1, having a restriction site adjacent to and upstream from the start (ATG) codon, and the same restriction site adjacent to and downstream from the stop (TGA) codon.
3. The gene of Claim 2 wherein the restriction sites are encoded by the nucleotide sequence GAATTC.
4. The gene of Claim 1, wherein the native sequence:

30

SEQ ID NO: 1

35

ATG AGG GGG ATG CTG CCC CTC TTT GAG CCC AAG 33

is altered to

40

SEQ ID NO: 2:

ATG CGT GGT ATG CTG CCT CTG TTT GAG CCG AAG . 33

45

5. A thermostable Thermus aquaticus DNA polymerase, having as the first amino acid sequence in the mature protein:

50

SEQ ID NO: 9:

Met-Asp-Tyr-Lys-Asp-Asp-Asp-Lys.
1 5

55

6. A method of increasing the production of Taq polymerase comprising the steps of:

A) providing a vector with a gene for Taq polymerase wherein the sequence of the first thirty nucleotide bases in the native gene which code for the first ten amino acids in the mature native protein, has been changed

i) by substituting therefor a modified nucleotide sequence selected from the group consisting of:

SEQ ID NO: 2:

ATG CGT GGT ATG CTG CCT CTG TTT GAG CCG AAG , 33

SEQ ID NO: 3:

ATG CGT GGG ATG CTG CCC CTC TTT GAG CCC AAG , and 33

SEQ ID NO: 4:

ATG GAC TAC AAG GAC GAC GAT GAC AAG CGT GGT ATG 36
CTG CCC CTC TTT GAG CCC AAG , 57

or

ii) by inserting between the start codon (ATG) of the mature native protein and the codon, (AGG) for the second amino acid of the mature native protein, the sequence:

SEQ ID NO: 8

TAC AAG GAC GAC GAT GAC AAG , 24

B) transfecting a compatible E. coli host with the vector of A) thereby obtaining transformed E. coli host cells; and

C) culturing the transformed cells of B) under conditions for growth thereby producing Taq polymerase synthesized by the transformed host cells.

7. The method of Claim 6 wherein the vector of step A has an inducible promotor.
8. The method of Claim 6 wherein the production of Taq polymerase is induced with isopropyl- β -D-thiogalactoside (IPTG).
9. A vector with a gene encoding Taq polymerase wherein the sequence of the first thirty nucleotide bases in the native gene which code for the first ten amino acids in the mature native Taq polymerase has been changed

A) by substituting therefor a modified nucleotide sequence selected from the group consisting of:

SEQ ID NO: 2:

ATG CGT GGT ATG CTG CCT CTG TTT GAG CCG AAG , 33

5

SEQ ID NO: 3:

ATG CGT GGG ATG CTG CCC CTC TTT GAG CCC AAG , and 33

10

SEQ ID NO: 4:

ATG GAC TAC AAG GAC GAC GAT GAC AAG CGT GGT ATG 36

CTG CCC CTC TTT GAG CCC AAG , 57

15

or

B) by inserting between the start codon (ATG) of the mature native protein and the codon, (AGG) for the second amino acid of the mature native protein, the sequence:

20

SEQ ID NO: 5:

GAC TAC AAG GAC GAC GAT GAC AAG , 24

25

said vector having:

- i) selectable markers,
- ii) a suitable promoter, and
- iii) proper regulatory sequences for controlling gene expression.

30

10. An E. coli host cell comprising the vector of Claim 9.

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50

55

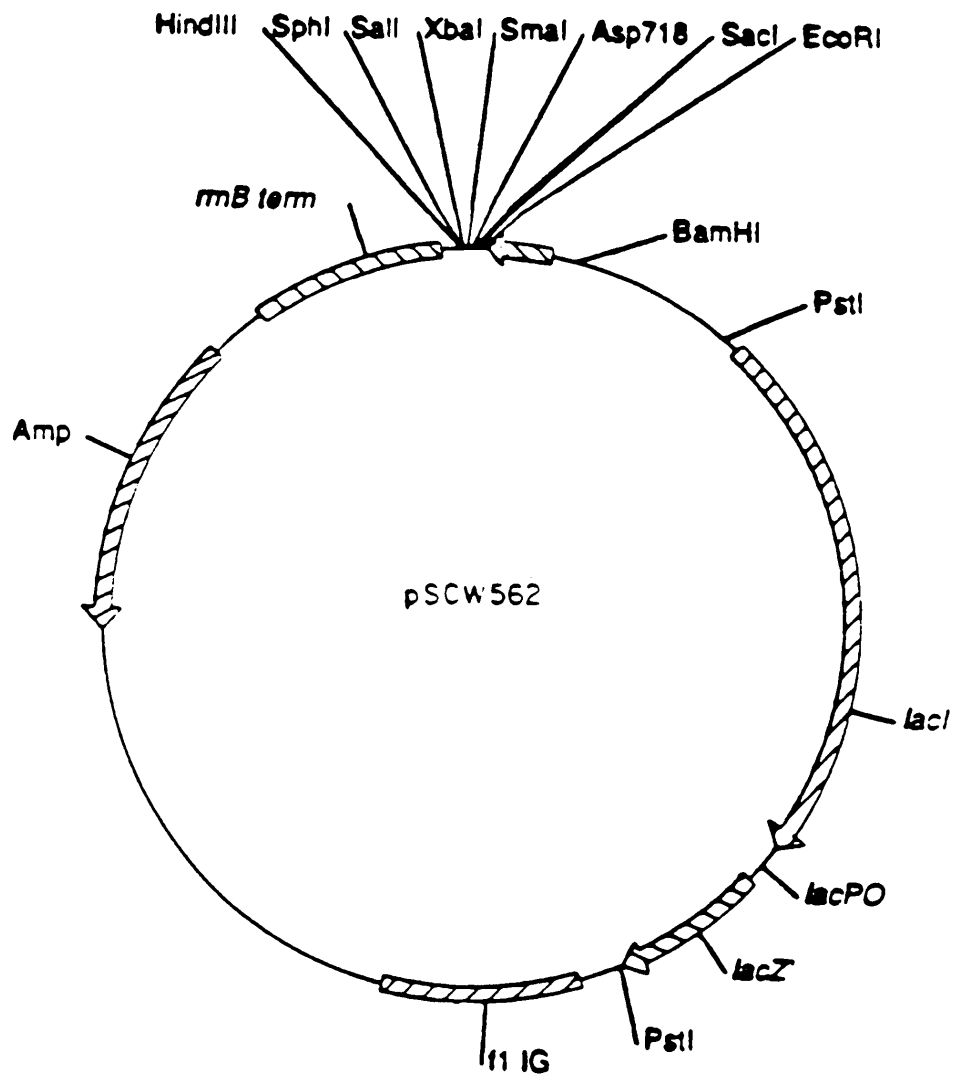


FIG. 1



European
Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 20 2731

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	BIOCHEMISTRY, vol. 29, no. 39, 2nd October 1990, pages 9274-9281, American Chemical Society, Washington, DC, US; N.P. GERARD et al.: "Construction and expression of a novel recombinant anaphylatoxin, C5a-N19, as a probe for the human C5a receptor" * Page 9275, left-hand column, lines 29-52; figure 1; page 9279, right-hand column, lines 3-19 * - - -	1,5,6	C 12 N 15/54 C 12 N 9/12 C 12 N 15/70 C 12 N 1/21 // (C 12 N 1/21 C 12 R 1:21)
Y	BIO/TECHNOLOGY, vol. 6, no. 10, October 1988, pages 1204-1210, Nature Publishing Co., NY, US; T.P. HOPP et al.: "A short polypeptide marker sequence useful for recombinant protein identification and purification" * Abstract; figures 1,2 * - - -	1,5,6	
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Y	NUCLEIC ACIDS RESEARCH, vol. 16, no. 7, 11th April 1988, pages 3013-3024, IRL-Press, Oxford, GB; F. BONEKAMP et al.: "The AGG codon is translated slowly in E.coli even at very low expression levels" * The whole document * - - -	1-10	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
Y	GENE, vol. 58, no. 1, 1987, pages 77-86, Elsevier Science Publishers B.V., Amsterdam, NL; N. LEE et al.: "Modification of mRNA secondary structure and alteration of the expression of human interferon alpha1 in Escherichia coli" * The whole document * - - - -/-	1-10	C 12 N
The present search report has been drawn up for all claims			
Place of search		Date of completion of search	Examiner
The Hague		20 November 91	HORNIG H.O.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			



European
Patent Office

EUROPEAN SEARCH REPORT

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,Y	JOURNAL OF BIOLOGICAL CHEMISTRY, vol. 264, no. 11, 15th April 1989, pages 6427-6437, American Society for Biochemistry and Molecular Biology, Inc., US; F.C. LAWYER et al.: "Isolation, characterization, and expression in Escherichia coli of the DNA polymerase gene from Thermus aquaticus" * The whole document *	1-10	
Y	WO-A-8 903 886 (ONCOGEN) * Claim 1; page 3, lines 6-37 *	1-10	
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